MICROWAVE ENGINEERING
PRACTICAL FILE
(ETEC-352)

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For the award of the degree of

Bachelor of Technology
In
Electronics & Communication Engineering

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EXPERIMENT-1

OBJECTIVE: To study and verify Microwave Components and Devices in detail.

THEORY:

- **RECTANGULAR WAVEGUIDES:** Waveguides are manufactured to the highest mechanical and electrical standards and mechanical tolerances L and S band waveguides are fabricated by precision bronzing of brass-plates and all other wave guides are in excursion quality, wave guide selections of specified lengths can be supplied with hangs, pointed outside and silver are gold plated inside.

- **FIXED ATTENUATORS:** Fixed Attenuators are meant for inverting a known attenuation in a waveguide system. These consists of a lossy wave inserted in a section of wave guide, hanged on both ends. These are useful for wave guide circuits, padding and extending the range of measuring instruments. Fixed attenuators are available for 3,6- or 10-dB attenuation values, but any attenuation value between 0 to 30 dB can be provided.

- **MULTIHOLE DIRECTIONAL COUPLERS:** These consist of sections of waveguide with addition of a second parallel section of waveguide thus making it a four-point network. However, 4thport is terminated with a matched load. These two parallel sections are coupled to each other through many notes, almost to give uniform coupling; minimum frequency sensitivity and high directivity. These are available in 3 ,6 ,10 ,20 and 40 dB coupling.

- **SLIDE SCREEN TUNERS:** These consist of section of waveguide hanged on both ends and a thin slot is provided in the broad wall of the waveguide. A carriage carrying the screw is provided over the slot. A VSWR up to 20 can be tuned to a value less than 1.02 at center frequency.

- **CIRCULATORS:** Circulators are matched three port devices and these are meant for allowing microwave energy to flow in clockwise direction with negligible loss but almost no transmission in anti-clockwise direction.

- **E-PLANE TEE:** E plane tee are series type T- junctions and consists of three sections of waveguide joined together in order to divide and compare power levels. The signal entering the first port of this T- junction will be equally dividing at second and third ports of the same magnitude but in opposite phase.

- **H-PLANE TEE:** H- plane Tee is shunt type T- junction for use in conjunction with VSWR meters, frequency meters, and other detector devices, like in E-plane tee, the signal fed through first point of H-plane tee will be equally divided in magnitude at second and third points but in same phase.

- **MAGIC TEE:E-H**: Tee consist of a section of waveguide in both series and shunt wave guide arms, mounted at the exact mid- point of main arm. Both ends of the section wave guide and both arms are allowed fringed on their ends. These tees are employed in balanced mixers, AFC circuits and impedance measurement circuits etc. This becomes a four-terminal device where are terminal is isolated from the input terminal.

- **WAVEGUIDE DETECTOR MOUNT (TUNABLE):** Tunable Detector mount is simple and easy to use instrument for detecting microwave power through a suitable detector. It consists of a detector crystal mounted in a section of a waveguide and shorting plunger for matching purpose. The output from the crystal may be fed to an indicating instrument. In K and R bands detector mounts the plunger is driven by a micrometer.

- **KLYSTRON MOUNT:** Klystron mounts are meant for mounting corresponding Klystron. These consists of a section of wave guide franged on one end and terminated with a movable short on the other band. An octal base with cable is provided for Klystron.

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- **MOVABLE SHORT:** It consists of a section of wave – guide, fringed on one end and terminated with a movable shorting plunger on the other end. By means of this no. Contacting type plunger, a reflection co-efficient of almost unity may be obtained.

- **PIN MODULATORS:** Pin modulators are designed to modulate the CW output of gunn oscillators. It is operated by the square pulses derived from the UHF(F) connector of gunn power supply. These consists of a pin diode mounted inside a section wave guide fringed on its both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.

- **GUNN POWER SUPPLY:** Model X-110 Gunn Power Supply comprises of a regulated DC- power supply and a square wave generator, designed to operate Gunn oscillator model 2161 and 2162 and pin modulators model 461 respectively.
  The DC voltage and variable from 0- 10 V. The front panel meter monitors the Gunn voltage and current drawn by gunn diode. The square wave of operators is variance from 0- 10 V, in amplitude and 900 - 1100 Hz in frequency.
  The power supply has been so- designed to protect gunn diode from reverse voltage application over transient and low frequency oscillators by negative resistance of gunn – diode.

RESULTS: Thus, all the microwave components were studied and verified in detail.

DISCUSSIONS:

- A waveguide is a structure that causes a wave to propagate in a chosen direction.
- The effect of losses on the propagating wave is due to the materials response to either the electric or magnetic field.
- There is an interdependence between the electric and magnetic fields when microwaves propagate through space.

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EXPERIMENT-2

OBJECTIVE: To determine frequency and wavelength in a rectangular waveguide.

APPARATUS: Klystron tube, Klystron power supply, Klystron mount, frequency meter, variable attenuator, slotted section, tunable probe, VSWR meter, waveguide stand, movable short/ matched termination.

THEORY: For dominant mode TE_{10} mode in rectangular waveguide $\lambda_o, \lambda_g, \lambda_c$ are related as follows:

$$\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

Where, λ_o = Free space wavelength, λ_g = Guided wavelength and λ_c = Cut-off wavelength.
For TE_{10} mode, $\lambda_c = 2a$, where "a" is the base broad dimension of waveguide.

BLOCK DIAGRAM:

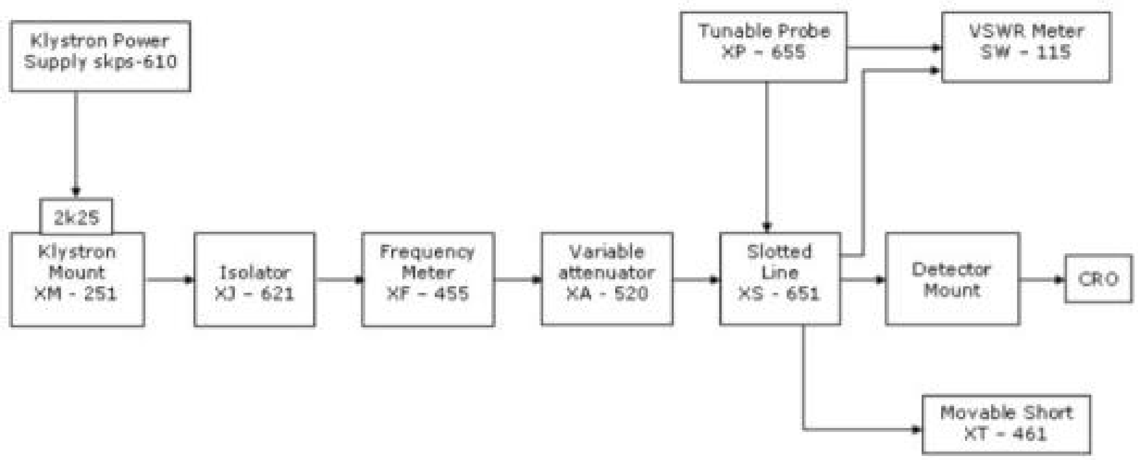

FIG: SET UP FOR FREQUENCY AND WAVELENGTH MEASUREMENT

PROCEDURE:

- Set up the component and equipment.
- Set up the variable attenuator at maximum position.
- Keep the control knobs of VSWR meter as below:
  - Range dB = 50dB position
  - Input Switch = Crystal low impedance
    - Meter Switch = Normal Position
    - Gain (Coarse and Time) = Mid Position
- Keep the control knobs of Klystron Power Supply as below:
  - Meter Switch = OFF
  - Mode Switch = ON
  - Beam Voltage Knob = Fully Anticlockwise

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- AM Amplitude Knob = Around Fully Clockwise
  - AM Frequency Knob = Around Mid Position
- 'ON' the Klystron Power Supply, VSWR Meter and cooling fan.
- Turn the meter switch OFF, power supply to beam voltage position and set beam voltage at 300V with the help of beam voltage knob.
- Adjust the reflector voltage to get some deflection in VSWR meter.
- Maximize the deflection with AM amplitude and frequency control knob of power supply.
- Turn the plunger of Klystron mount for maximum deflection.
- Turn the frequency meter knob to get the 'dip' on the VSWR scale and note down the frequency directly from VSWR frequency meter.

OBSERVATIONS AND CALCULATIONS:

F(gen) = 9.5 GHz
a = 2.286
$\lambda_o = 2a = 2 \times 2.286 = 4.572$ cm
$\lambda_g = (2^{nd} - 1^{st}) = 12.73 - 8.25 = 4.48$ cm

We know that,

$$\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

$$\lambda_o = \frac{\lambda_g \lambda_c}{\sqrt{\lambda_g^2 + \lambda_c^2}}$$

$$\lambda_o = \frac{4.48 \times 4.572}{\sqrt{(4.48)^2 + (4.572)^2}} = 3.2 \text{ cm}$$

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{3.2} = 9.375 \ Hz$$

RESULT: Frequency = 9.315 GHz and Wavelength = 3.2 cm

DISCUSSIONS:

- Rectangular waveguides guide EM energy between four connected electrical walls, and there is little current created on the walls.
- A rectangular waveguide supports many different modes, but it does not support the TEM mode.

EXPERIMENT-3

OBJECTIVE: To study and verify the isolator.

APPARATUS REQUIRED: Klystron tube, Klystron power supply, Klystron mount, isolator, slotted section, tunable probe, frequency meter, variable attenuator, and Detector mount, wave guide stand, cooling fan, VSWR meter, cables and accessories.

THEORY:

- **ISOLATOR:** The isolator is a 2-port device with small insertion loss in forward direction and a large in reverse attenuation.
- **CIRCULATOR**: The circulator is multiport function that permits transmission in certain ways, a wave incident in port 1 is coupled to port 2 only, a wave incident at port 2 is coupled to port 3 only and so on.

THE BASIC PARAMETERS OF ISOLATOR AND CIRCULATOR:

A. INSERTION LOSS: The ratio of power supplied by source in the input port to the power detected by a detector in the coupling i.e., with other port terminated in the load, is defined as Intersection loss or forward loss.

B. ISOLATION: It is the ratio of power fed to input to the input power detected at not equal port with other port terminated in the matched load.

C. INPUT VSWR: The input VSWR of an isolator or circulator is the ratio of voltage maximum to voltage min. of the standing wave existing on the tube when I port of it termination the line and others have matched terminators.

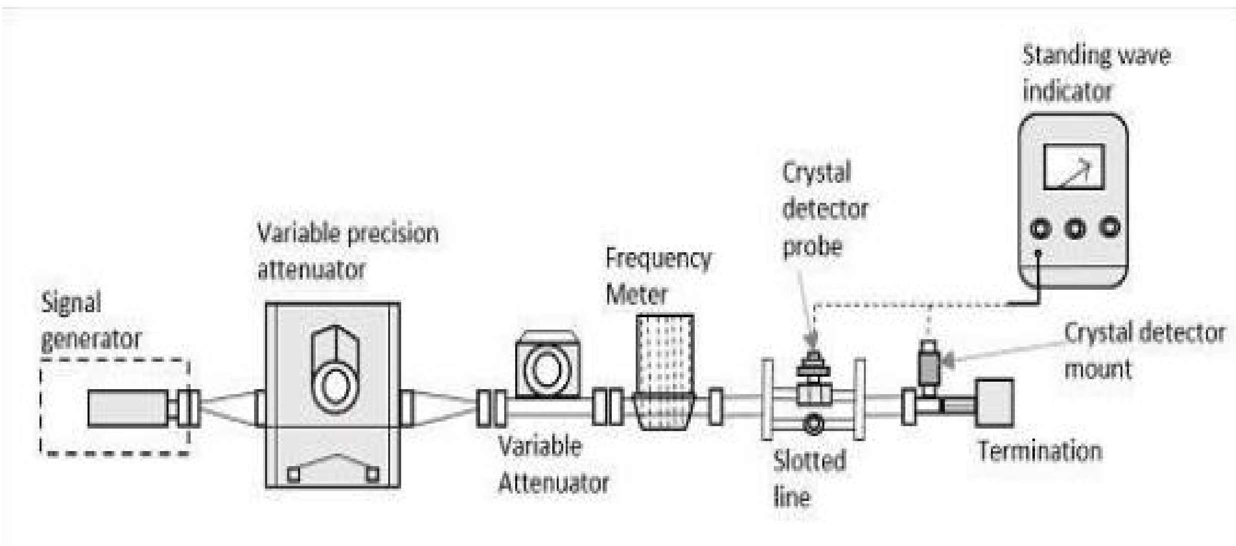

Fig. 3.1: Measurement of VSWR

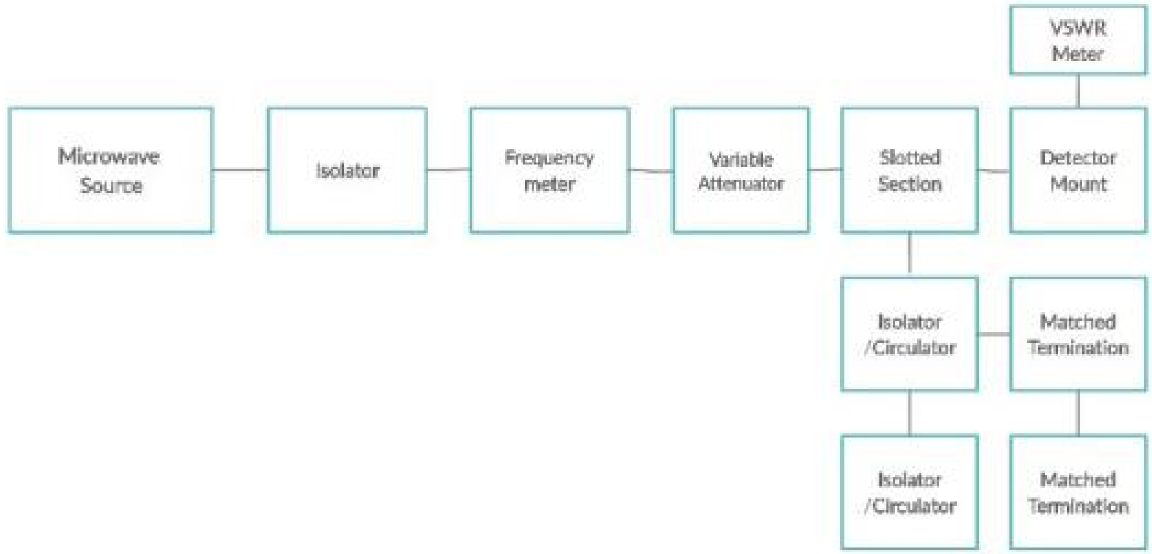

Fig. 3.2: Block Diagram Measurement of Insertion Loss and Isolation

PROCEDURE:

a) **Input VSWR measurements:**
   1. Set up the components and equipment as shown in i/p point of isolator or circulator towards slotted line and matched load on other ports of it.
   2. Energize the microwave source for particular operation of frequency.
   3. With the help of slotted line, probe and VSWR meter find out SWR of the isolator or circulator as describe earlier for low and medium SWR measurements.
   4. The above procedure can be repeated for other ports or for other frequencies.

b) **Measurement of insertion loss and isolation:**
   1. Remove the probe and isolator or circulator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with VSWR meter.
   2. Energize the microwave source for maximum output for a particular frequency of observation. Tune the detector mount for maximum output in VSWR meter.
   3. Set any reference level of power in VSWR meter with the help of variable attenuator gain control knob of VSWR meter and note down the reading.
   4. Carefully remove the detector mount from slotted line without disturbing the position of set up. Insert the isolator/circulator b/w slotted line and detector mount. Keeping input port to slotted line and detector at the output port. A matched termination should be placed at third port in case of circulator.
   5. Record the reading in VSWR meter. If necessary change automatically switch to high or lower position and taking 10db change for one set change of switch position.
   6. Compute insertion loss on P1-P2 in db.
   7. Record the reading of VSWR meter after installing the isolator or circulator.
   8. Compute isolation as P1-P3 in dB.
   9. The same experiment can be done for other ports of circulator.
   10. Repeat the same for other frequency.

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OBSERVATION AND CALCULATIONS:

Total power Pt = 0.013mw

Power at port 1 (Pt) = 0.013mw

Power at port 1 (Pt) = 0.007mw

Insertion Loss = -10 log10 (Pt- Pi /Pt) dB

= -10 log10 [(0.013 – 0.007)/0.013]

=3.3579 dB

RESULT:

Measure values are as follows:

Total load: 0.15mw

Insertion loss: 0.3579 db.

Power at Port 1:0.013mw

Power at Port2:0.007mw

DISCUSSIONS:

- The isolator is a switch which isolates the part of the circuit system when it is required.
- Isolators are generally used at the end of the breaker to repair or to replace.

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EXPERIMENT-4

OBJECTIVE: To study and verify E-plane Tee.

APPARATUS REQUIRED: Microwave sources, variable attenuator, frequency meter, slotted line, tunable probe, E-Tee, and matched termination, waveguide stand, detector mount VSWR meter.

THEORY: E-plane tee are series type tee-junction and consist of 3-section of waveguide joined together in order to divide or compare power levels the signal entering the first port at this or junction will be equally divided at second and third port of the same magnitude but in opposite phase.

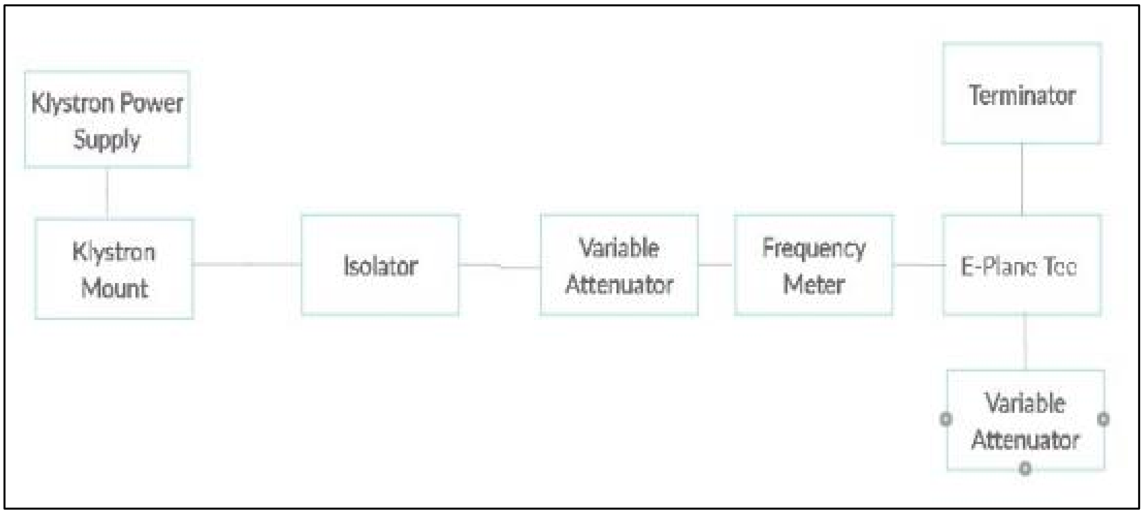

Fig. 4.1: Setup Component and Equipment

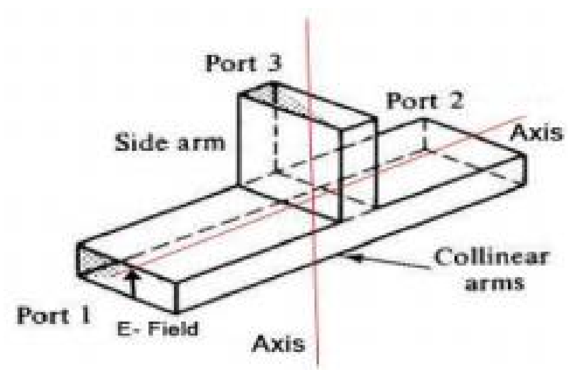

Fig. 4.2: E-Plane Tee Diagram

PROCEDURE:

1. **VSWR measurement of phase:** Energy microwave source for particular frequency of operation and the meter detector mount for maximum output measure VSWR of side arm as described in measurement of SWR for low and maximum value connect another arm to line and terminate other port with matched termination measure VSWR as above.

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2. **Measurement of isolation and coupling coefficient:** Remove tunable probe and magic tee from the slotted line and connected the detector mount to slotted line. Energize the microwave source for particular frequency of operational and meter on a time detector mount of maximum output.

OBSERVATIONS AND CALCULATIONS:

- POWER AT PORT (3) = 6.310mw
- POWER AT PORT (1) = 2.512mw
- POWER AT PORT (2) = 2.512mw

Loss Percentage: $= \dfrac{\text{INPUT POWER} - \text{OUTPUT POWER}}{\text{INPUT POWER}} * 100$

$= \dfrac{(6.310 - 5.024)}{6.310} * 100$

$=$ 20.38% [In Opposite Phase]

Output power: = Power at Port 1 + Power at Port 2

= 2.512+2.512

= 5.024 mw

RESULT: Experiment is set up E-plane tee is studied.

PRECAUTIONS:

- Ensure tight connection of apparatus.
- Use established power supply.
- Avoid cross connection of threads
- Use fan to keep Klystron temperature low.

DISCUSSIONS:

- An E-Plane Tee junction is formed by attaching a simple waveguide to the broader dimension of a rectangular waveguide, which already has two ports.
- E-plane Tee is also called as Series Tee.

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EXPERIMENT-5

OBJECTIVE: To study and verify the function of H-plane tee.

APPARATUS REQUIRED: Microwave source, isolator, variable attenuator, frequency meter, slotted line, tunable probe, H-tee, matched termination, waveguide, stand, detector mount, VSWR meter and accessories.

THEORY: H-plane Tee are shunt type T-junction for use in conjunction with VSWR meters, frequency meters and other detector devices. Like E-plane tee, the signal is fed into the first part of the H-plane Tee will be equally divided in magnitude at second and third ports but in same place.

An H-type T-junction is illustrated in the figure. It is called H-type T-junction because the long axis of the 'B' arm is parallel to the plane of magnetic lines of force in magnitude. The E-field is fed into arm A and in phase outputs are obtained from B and C arms. The reverse is also true. H-plane tee is so called because the axis of side arm is parallel to the planes of main transmission lines. As all the three arms of the H-plane tee in the magnetic field divide themselves into arms, it is also called a current junction.

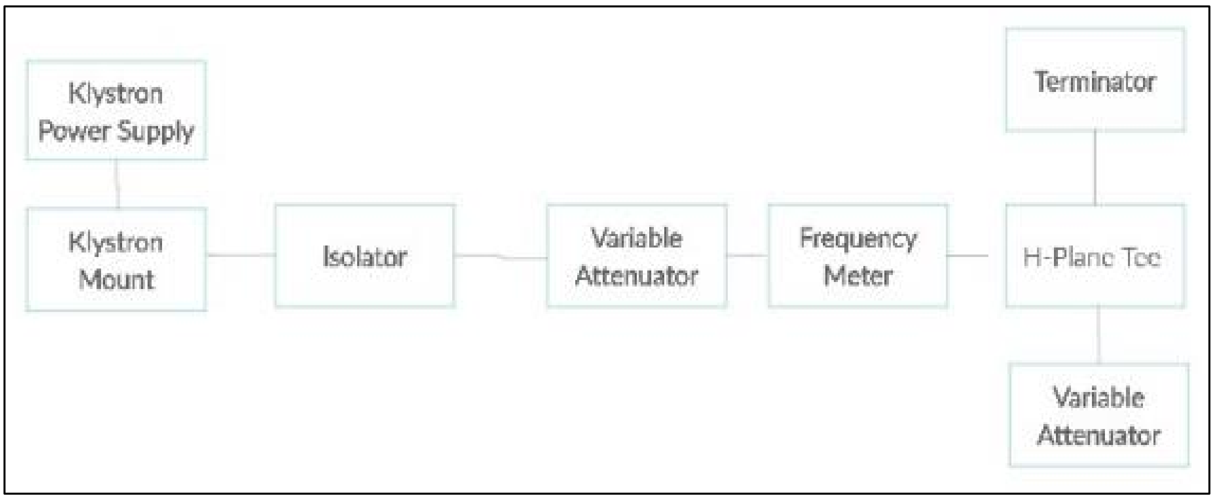

Fig. 5.1: Setup Component and Equipment

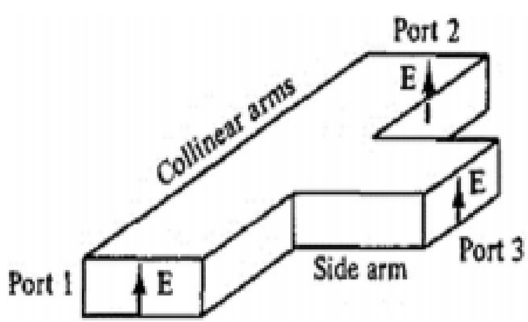

Fig. 5.2: H-Plane Tee Diagram

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PROCEDURE:

VSWR Measurement of Ports

1. Energize microwave for a particular frequency.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the detector mount for maximum output with VSWR meter.
3. Set any reference level of power in VSWR meter with the help of variable attenuator gain control knob of VSWR meter and note down threading.
4. Carefully remove the detector mount from slotted line without disturbing the position of setup. Insert the isolator/ circular between slotted line and detector at its output port. A matched termination should be placed at third port in case of circulator.
5. Record the reading in VSWR meter. If necessary, change automatically set to high or low position taking 10 dB change for one set change of switch position.
6. Compute insertion loss, the isolator or circulator has to be connected to P1-P2 in dBs.
7. For measurement of isolation, the isolator or circulator has to be connected reverse i.e. output port to slotted line an d detector to input port with other port terminated by described termination. After setting a reference level without isolator or circulator in the setup as described insertion loss measurement. Let same P1 level is set.
8. Record the reading of VSWR meter after inserting the isolator or the circulator.
9. Measurement of isolation and coupling Coefficients.
10. Remove tunable probe and magic tee from the slotted line and connect the detector mount to slotted line.
11. Energize the microwave source from particular frequency of equation and then the detector mount of maximum output.

OBSERVATIONS AND CALCULATIONS:

- Power at Port (3) = 10.00mω
- Power at Port (2) = 3.982mω
- Power at Port (1) = 3.982mω

Loss Percentage = $\frac{\text{Power at Port (3)} - [\text{Power at Port (1)} + \text{Port (2)}]}{\text{Power at Port (3)}} * 100$

$= \frac{10.00 - 7.964}{10.00} * 100$

$= 20.36\ \%$

Output Power = Power at Port (1) + Power at Port (2)

= 3.982 + 3.982

= 7.964 mω

RESULT: The function of H-tee plane is studied and verified.

PRECAUTIONS:

- Switch on the cooling fan near the Klystron tube to decrease heating effects.
- Do not see the rectangular waveguide with naked eyes.
- Set all the components like frequency meter, VSWR correctly.

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DISCUSSIONS:

- Folded H plane tee is one of the many components that can be used for the power division application.
- Its advantage is that the output arms and input arms are in a single plane along a single axis, thus taking less space in the overall system.

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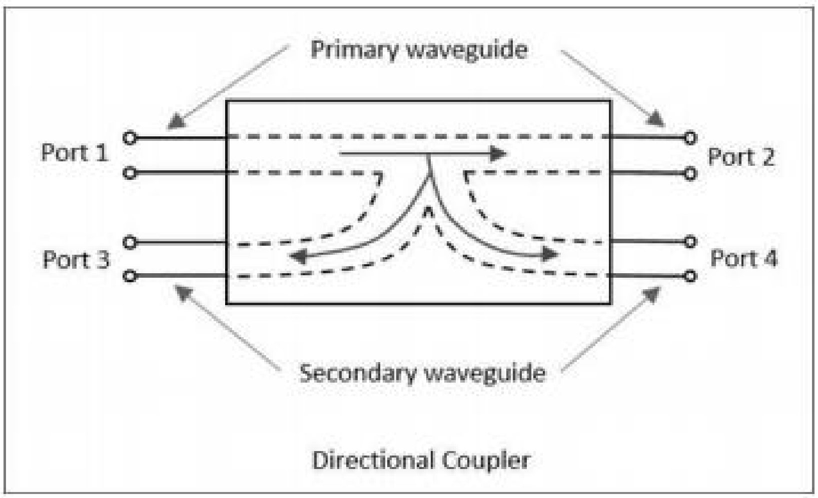
EXPERIMENT-6

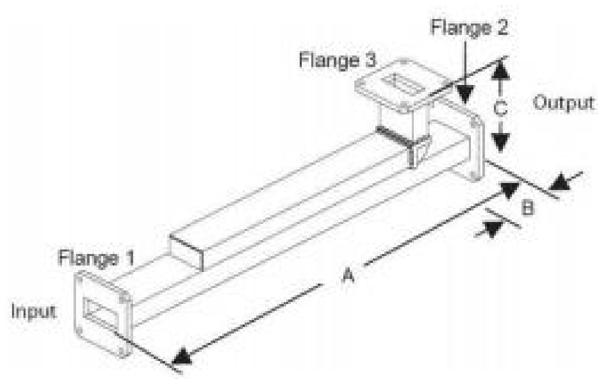
OBJECTIVE: To measure coupling factor and directivity of multiple directional couplers.

APPARATUS REQUIRED: Microwave source, isolator, frequency meter, variable attenuator, slotted line, detector, matched termination, waveguide, stand, VSWR meter.

THEORY: A directional coupler is a device with which it is possible to measure incident and reflected wave separately it consists to transmission line the main arm, the auxiliary arm electron magnetically coupled each other. The power entering port 1 in the main arm divide between 2 and 4 and almost no power in Port 2 divide between port 1 and ports 3 with port 4 sealed.

COUPLING FACTOR: Ratio of input power to force forward power 10*log 10 (0p1/p4). Port 3 terminal with built in Terminator 2 power is entering at PORT 1.





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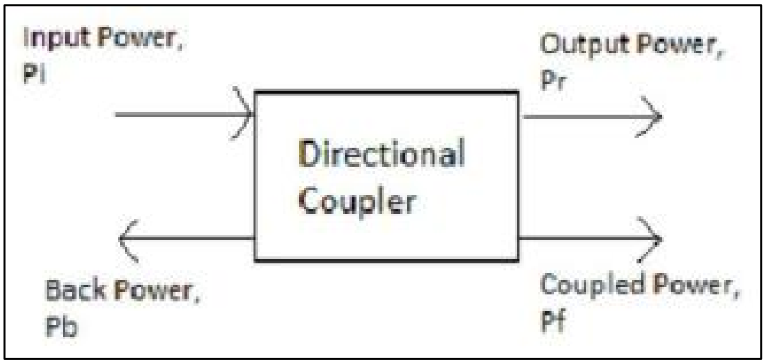

PROCEDURE:

1. Set up new bench accordingly.
2. Energize the microwave source for particular frequency.
3. Connect the port 1 to power output side and observe the power distribution in Port 3 ,2 &4 Similarly, if possible, give input to port 2 and check power distribution to other port 1, 3 &4.

OBSERVATIONS AND CALCULATIONS:

- POWER AT PORT 1 = 3.982 MW
- POWER AT PORT 2 = 1.259 MW
- POWER AT PORT 4 = 0.002 MW

Coupling Factor = $10 \log_{10} (P1/P2)$
$= 10 \log_{10} (3.982/0.002)$
$= 32.99\text{dB}$

Directivity = $10 \log_{10} (P2/P1)$
$= 10 \log_{10} (1.259/3.982)$
$= 5.007 \text{ dB}$

RESULT: Power coupling in directional coupler is studied.

PRECAUTIONS:

- Switch on the cooling fan near klystron tube to keep it cool.
- Do not see inside the rectangular waveguide by naked eyes.
- Set all the components easily.

DISCUSSIONS:

- A **directional coupler** is a 4-port device that is used to sample a small amount of input signal power for measurement purposes.
- Their basic **function** is to sample RF signals at a predetermined degree of coupling, with high isolation between the signal ports and the sampled ports which supports analysis, measurement and processing for many applications.

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EXPERIMENT-7

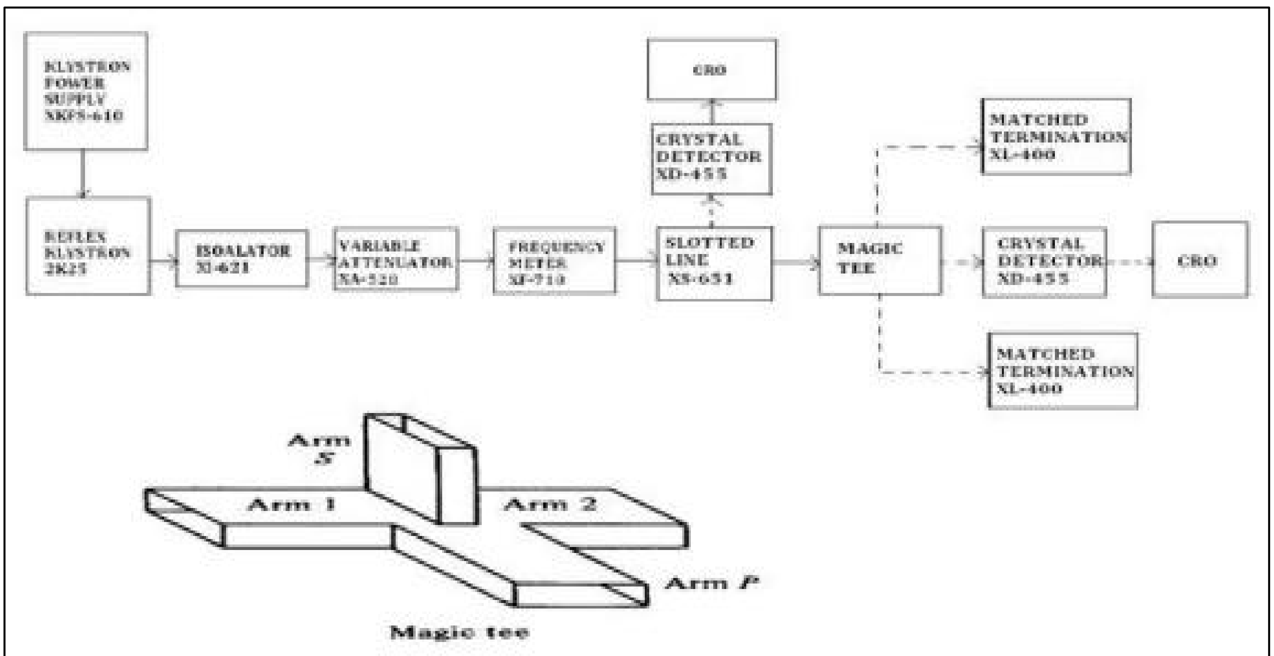
OBJECTIVE: To study and verify magic tee.

APPARATUS REQUIRED: Microwave source, isolator variable attenuator frequency meter, slotted line, tunable probe, magic tee, matched termination, waveguide stand, detector mount, VSWR meter and accessories.

THEORY: The device magic tee is a combination of E and H plane Tee. Arm 3, the H arm forms an H-plane Tee and arm 4, the E arm, forms and E-plane Tee in the combination of arm 1 and 2 as side or collinear arms. If the power is fed into arm 3 (H-arm), the electric field divides equally between arm 1 and 2 with the same phase and no electric field exist in arm4. Reciprocity demands no coupling in port-3 (H-arm); if power is fed in arm 4 (E-arm), it divides equally into arm 1 and 2 but out of phase with no power to arm 3. Further, if the power is fed from arm 1 and 2 it is added in arm 3 (H-arm) and it is subtracted in E-arm i.e. arm 4.

The basic parameters to be measured for magic tee are defined below:

1) Input VSWR: value of SWR corresponding to each port, as a load to the line while other ports are in matched load.
2) Isolation: The isolation between E and H arms is defined as the ratio of power supplied by the generator connection to the E-arm (port-4) to the power detected at the H-arm (port-3) when side arms 1 and 2 are terminated in matched load. Hence, isolation 3-4 =10 log10 (P4/P2)
   Similarly, isolation between other parts may also be defined.
3) Coupling Coincident: It is defined as $C_{ij}=10^{-\alpha/20}$ where α is attenuation /isolation do when it is input arm and i is output arm.
   Then $\alpha=10 \log_{10} (P_i/P_j)$
   where Pi is the power delivered to arm I and Pj is power detected at the j arm.



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PROCEDURE:

- VSWR measurement of the Ports:
  - Setup the components and equipment keeping E-arm towards, slotted line and matched termination of other ports.
  - Energize the microwave source for particular frequency operation.
  - Measure the VSWR of E-arm as described in measurement of SWR for low and medium value.
  - Connect another arm to slotted line terminated the other part with matched termination. Measure the GVSWR. YSWR of any port can be measure.
- Measurement of isolation and coupling coefficient:
  - Remove the tunable probe and magic tee from the slotted line and connect the detector mount to slotted line.
  - Energize the microwave source for the particular frequency of operation and tine the detector mount for max output with the help of variable attenuator gain control knob of VSWR meter, set only power |V| in VSWR meter and note down. Let it be P3.
  - Without disturbing the position of variable attenuator and gain control knob, carefully place slotted line detector to E-arm and matched terminated to arm 1,2.
  - Determine the isolation between port 3 and 4 as P3-P4in db.
  - Determine the coupling coefficient from equation given in the theory port.

OBSERVATION TABLE:

PORT 1	PORT 2	PORT 3	PORT 4
3.982	3.982	0	10.00
2.512	2.512	6.310	0

RESULT: Hence operation of magic-Tee has been studied and verified.

PRECAUTIONS:

- Set the apparatus carefully.
- Use cooling fan to keep the klystron tube cool.
- Note the reading carefully.

DISCUSSIONS:

- Magic Tee consists of both H-plane Tee and E-plane Tee. The arm of waveguide makes two ports called collinear port i.e. port 1, H-arms i.e. port 2 &3, and E-arm i.e. port 4. E-arm is difference port or series port. H-arm is sum port or parallel port. Magic Tee can also be used to measure the impedance.

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EXPERIMENT-8

OBJECTIVE: To study and verify operation of circulator.

APPARATUS REQUIRED: Microwave source, isolator, circulator, frequency meter, variable attenuator, slotted line, tunable probe, detector mount, VSWR meter, test circulation and accessories.

THEORY: The circulator is a multiport junction that permits transmission in certain ways. A wave incident in port 1 is coupled to port 2 only, a wave incident to port 2 is coupled to port 3 only and so on, and following are the basic components.

- **Insertion Loss:** It is the ratio of power fed to i/p arm to the power detected by a detector is coupling arm, i.e., o/p arm with other port terminated in the matched load, is defined as insertion loss.
- **Isolation:** It is the ratio of power fed to input arm and the power detected at not coupled port with other port terminated in matched load.
- **Input VSWR**: The input VSWR of a circulator in the ratio of voltage max. M to voltage minimum of the standing wave existing on the line, when one port of is terminated the line other have matched termination.

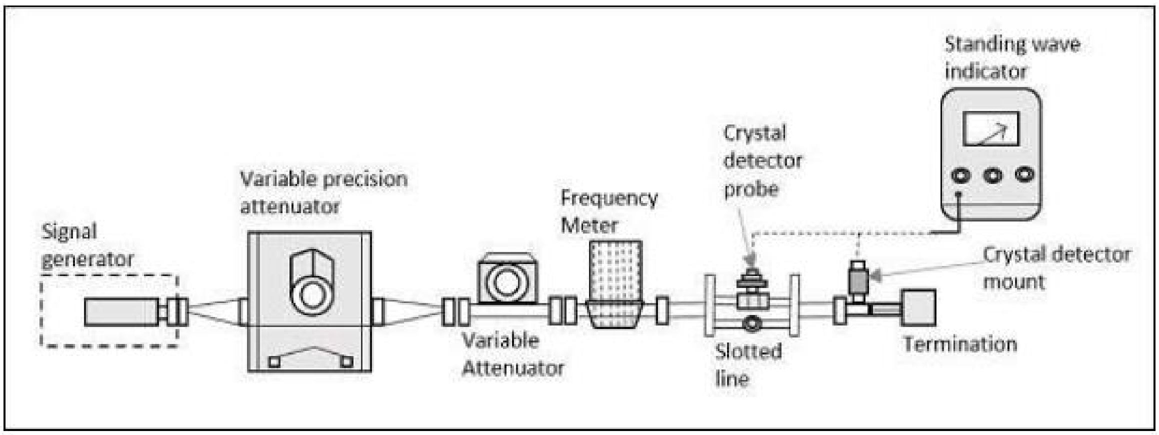

Fig. 8.1: Measurement of VSWR of Circulator

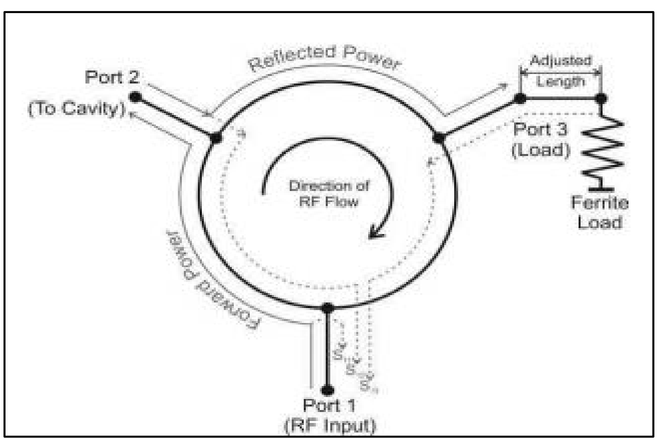

Fig. 8.2: Circulator Diagram

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PROCEDURE:

a) **Input VSWR measurement:**
   - **a.** Set up the components and equipment input of circulator towards slotted line and matched load on other ports of it.
   - **b.** Energize the microwave power of particular operation of frequency.
   - **c.** With the help of slotted line, probe and VSWR meter find out SWR of circulator.
   - **d.** Repeat above procedure for other ports.

b) **Measurement of insertion loss and isolation:**
   - **a.** Remove the probe and circulator from slotted line connected to the detector mount to slotted section. The O/p of detector mount should be connected with VSWR meter.
   - **b.** Energize the microwave source for maximum o/p for a particular frequency of operation. Tune the detector mount for maximum o/p in the VSWR meter.
   - **c.** Set any reference level of power in VSWR meter with the help of variable attenuator and gain control knob of VSWR meter. Let it be P1.
   - **d.** Carefully remove the detector mount from slotted line without disturbing position of set up. Insert the circulator disturbing position of set up. Insert the circulator b/w slotted line and detector mount. Keeping input port to slotted line and detector at its o/p port.
   - **e.** Record the reading of VSWR meter inserting the circulator.
   - **f.** Compute isolator at P1-P2 in Db.

OBSERVATIONS AND CALCULATIONS:

Total Power P_t = 0.013mw
Power at Port (1) = 0.031 mW
Power at Port (2) = 0.008 mW
Power at Port (3) = 0 mW

Insertion Loss = $-10 \log_{10} (P_{out}/P_{in})$ dB
= $-10 \log_{10} (0.008/0.013)$
= 2.108 dB

RESULT: The function of circulator has been studied and verified.

PRECAUTIONS:

- Set the apparatus carefully.
- Use cooling fan to keep the Klystron cool.
- Note the reading carefully.

DISCUSSIONS:

- It has many applications as it is lossless and non-reciprocal device.
- The 3-port circulator can be used as RF isolator by terminating one of its port.

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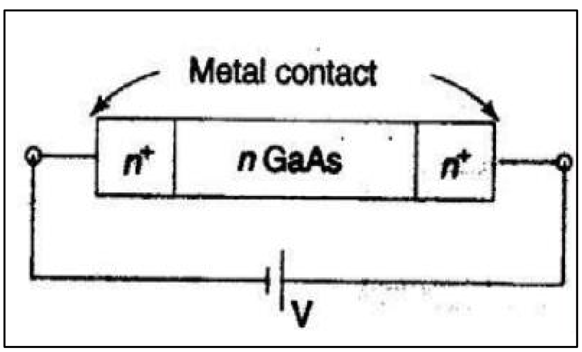
EXPERIMENT-9

OBJECTIVES: To Study the Following Characteristics of Gunn diodes:

- V-I Characteristics.
- Output Power and frequency as a function of voltage.

APPARATUS REQUIRED: Gunn oscillator, Gunn power supply, PIN modulator, Isolator, Frequency meter, Variable attenuator, Detector mount, Slotted section with probe carriage, VSWR meter.

THEORY: Gunn Diodes (Transferred Electron Devices): Gunn diodes are negative resistance devices which are normally used as low power oscillator at microwave frequencies in transmitter and also as local oscillator in receiver front ends. These are semiconductors having a closely spaced energy valley in the conduction band as shown in Fig. for GaAs. When a dc voltage is applied across the material, an electric field is established across it. At low E-field in the material, most of the electrons will be located in the lower energy central valley Γ. At higher E-field, most of the electrons will be transferred in to the high-energy satellite L and X valleys where the effective electron mass is larger and hence electron mobility is lower than that in the low energy Γ valley. Since the conductivity is directly proportional to the mobility, the conductivity and hence the current decreases with an increase in E-field or voltage in an intermediate range, beyond a threshold value V_{th} as shown in Fig. This is called the transferred electron effect and the device is also called 'Transfer Electron Device (TED) or Gunn diode'. Thus, the material behaves as negative resistance device over a range of applied voltages and can be used in microwave oscillators.



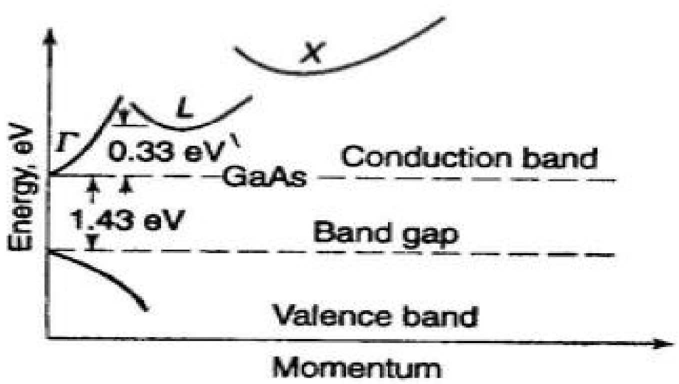


Fig. 9.1: Multi-valley conduction band energies of GaAs

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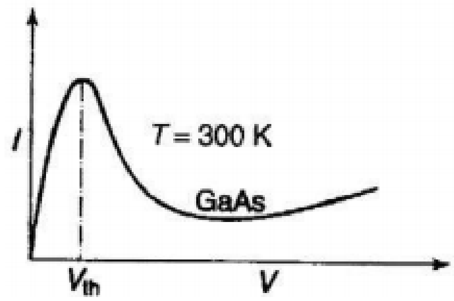
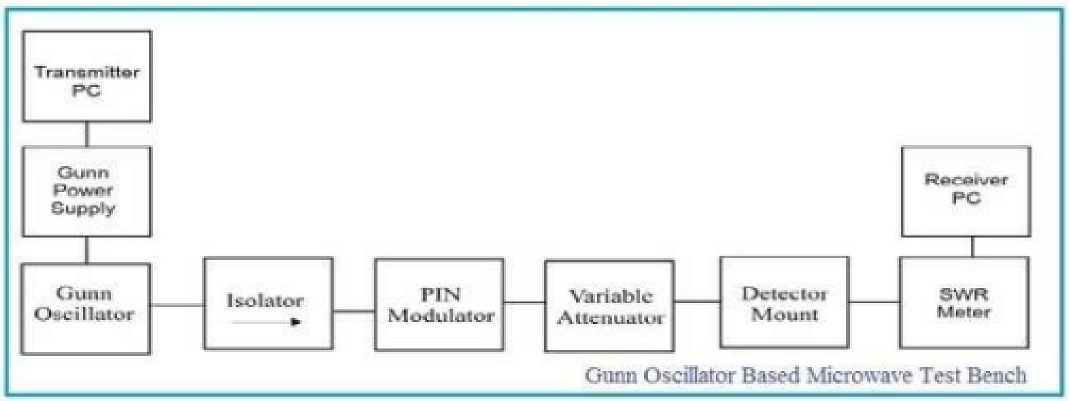


Fig. 9.2: Current-voltage characteristics of GaAs

Gunn Oscillator: In a Gunn Oscillator, the Gunn Diode is placed in a resonant cavity. In this case the oscillation frequency is determined by cavity dimension than by the diode itself. Although Gun Oscillator can be amplitude-modulated with the bias voltage, we have used separate PIN modulator through PIN diode for square wave modulation.



PROCEDURE:

1. Set the components and equipment as shown in the Fig.
2. Initially set the variable attenuator for maximum attenuation.
3. Keep the control knob of Gunn Power Supply as below:
   Meter Switch - 'OFF'
   Gunn bias knob - Fully anticlockwise
   Pin bias knob - Fully anticlockwise
   Pin Mod frequency Any position.
4. Keep the control knob of VSWR meter as below:
   Meter Switch - Normal
   Input Switch - Low Impedance
   Range dB switch - 40 dB
   Gain Control knob - Fully clockwise
5. Set the micrometer of Gunn Oscillator for required frequency of operation.
6. 'ON' the Gunn Power Supply, VSWR meter and Cooling fan.

I. Voltage-current characteristics

1. Turn the meter switch of 'Gunn power supply to voltage position.
2. Measure the Gunn diode Current Corresponding to the various voltage controlled by Gunn bias knob through the panel meter and meter switch. Do not exceed the bias voltage above 10volts.

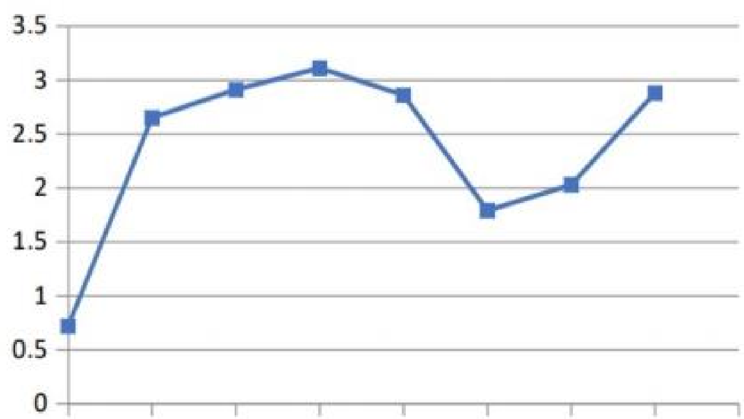
3. Plot the voltage and current readings on the graph as shown in Fig.
4. Measure the threshold voltage which corresponds to maximum current.

II. Output power and frequency as function of bias voltage

1. Turn the meter switch of Gunn power supply to voltage position.
2. Increase the Gunn bias control knob.
3. Rotate PIN bias knob to around maximum position.
4. Tune the output in the VSWR meter through frequency control knob of modulation.
5. If necessary, change the range dB switch of VSWR meter to higher or lower dB position to get deflection on VSWR meter. Any level can be set through variable attenuator and gain control knob of VSWR meter.
6. Measure the frequency by frequency meter and detune it.
7. Reduce the Gunn bias voltage in the interval of 0.5V or 1.0V and note down corresponding reading of output at VSWR meter and frequency by frequency meter.
8. Use the reading to draw the power vs Voltage curve and frequency vs voltage and plot the graph.
9. Measure the pushing factor (in MHz/Volt) which is frequency sensitivity against variation in bias voltage for an oscillator. The pushing factor should be measured around 8 Volt bias.

OBSERVATION TABLE:

Voltage (V)	Current (I)
0.44	0.67
2.03	2.65
2.41	2.91
3.00	3.11
3.28	2.86
3.60	1.79
4.53	2.03
5.34	2.88



V-I Characteristics

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RESULT: The characteristics of gunn diode has been studied.

DISCUSSIONS:

- Gunn diode will have efficiency of only few percentage. Commercial GUNN diode need supply of about 9V with operating current of 950mA and available from 4GHz to 100GHz frequency band. It is preferably placed in a resonant cavity.
- This is called the transferred electron effect and the device is also called 'Transfer Electron Device (TED) or Gunn diode'.

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EXPERIMENT-10

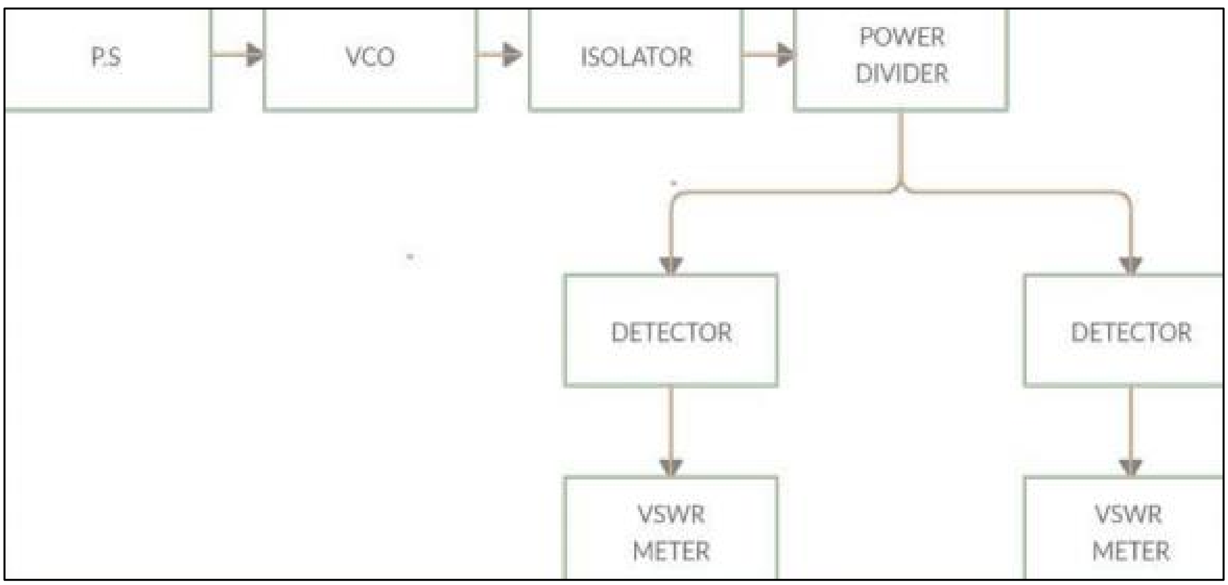
OBJECTIVE: To study and verify the characteristics of a microchip power divider

APPARATUS REQUIRED: VSWR meter, VCO (voltage-controlled oscillator), detector, micro strip power divider, voltage divider.

THEORY: The layout of the modified power divider in which all the perfectly matched at the centre frequency. An isolation resistance off 22 is added at the port 2 and 3. The scattering parameter of the modified divider at centre frequency are given by:

$$[S] = 1/\sqrt{2}\begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

It is interesting to note that all ports are simulated matched port 2 and 3 are also perfectly isolated. This type of power divider can be used as power combines as well power fed to port 2 and 3 gives entire power at port 1.



PROCEDURE:

- Set up the system as per diagram.
- Terminate port 3 in 50ohm matched load.
- Measure the input power fed to port 1 of the micro strip power divider circuits as a selected VCO frequency.
- Measure the reflected power by noting the reading of the detector connecting to the directional coupler and the forward power by the reading of the VSWR meter.
- Repeat the above step at 5-10 different frequency by turning the VCO.
- Plot the return loss and power couple to port 2 of the micro strip divider.
- Using the same procedure, plot power coupled to port (match terminated port 2).
- Terminate port 1 and fed power to port 2 and measure power available at port3.

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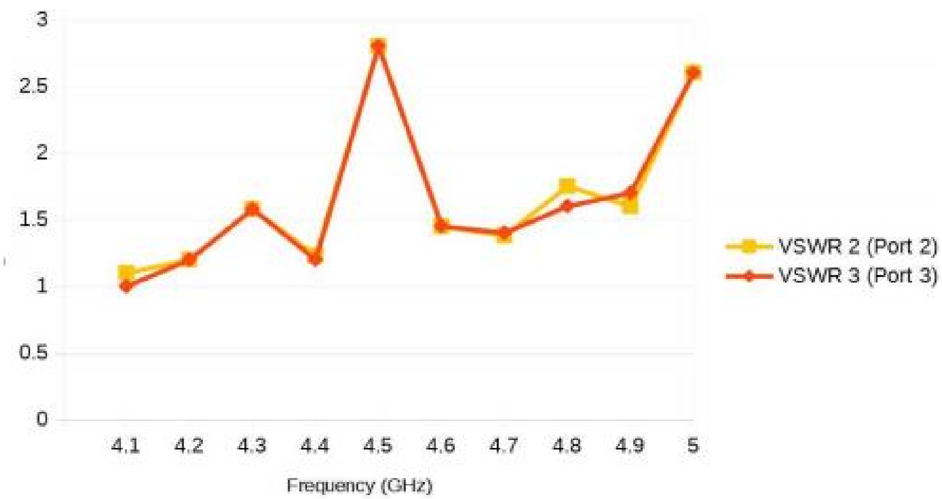
OBSERVATION TABLE:

S No.	Freq (GHz)	VSWR 2 (Port 2)	VSWR 3 (Port 3)
1	4.1	1.1	1
2	4.2	1.2	1.2
3	4.3	1.578	1.578
4	4.4	1.23	1.2
5	4.5	2.8	2.8
6	4.6	1.45	1.45
7	4.7	1.38	1.4
8	4.8	1.75	1.6
9	4.9	1.6	1.7
10	5	2.6	2.6



RESULT: The characteristics of micro strip power divider is studied and verified.

DISCUSSIONS:

- It is most robust design.
- It has matched output ports and hence will not have reflections.
- It provides better isolation between output ports than T-junction type **splitter**.

EXPERIMENT-11

OBJECTIVE: To study and verify H-plane Tee using HFSS Software.

SOFTWARE USED: HFSS Software

THEORY: H-plane Tee are shunt type T-junction for use in conjunction with VSWR meters, frequency meters and other detector devices. Like E-plane tee, the signal is fed into the first part of the H-plane Tee will be equally divided in magnitude at second and third ports but in same place.

An H-type T-junction is illustrated in the figure. It is called H-type T-junction because the long axis of the 'B' arm is parallel to the plane of magnetic lines of force in magnitude. The E-field is fed into arm A and in phase outputs are obtained from B and C arms. The reverse is also true. H-plane tee is so called because the axis of side arm is parallel to the planes of main transmission lines. As all the three arms of the H-plane tee in the magnetic field divide themselves into arms, it is also called a current junction.

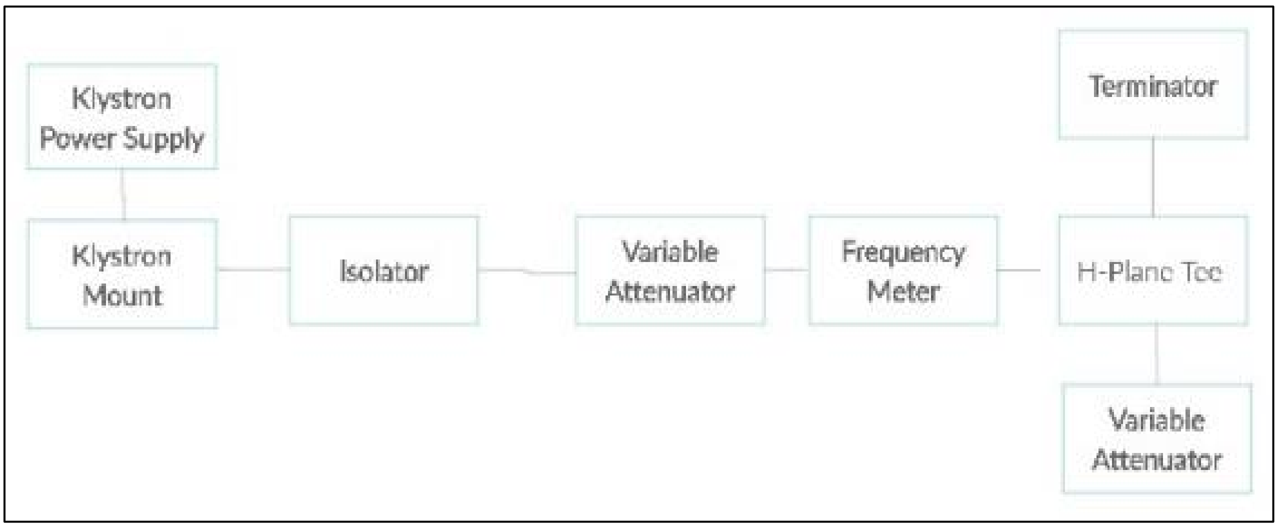


Fig. 5.1: Setup Component and Equipment

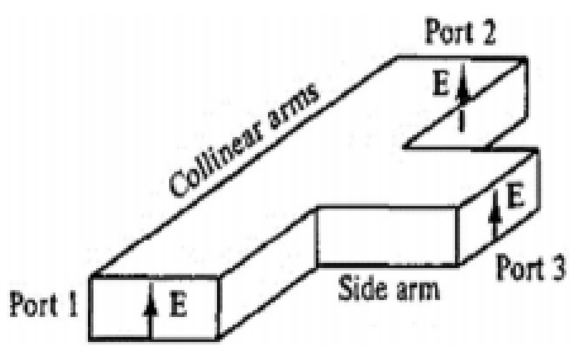
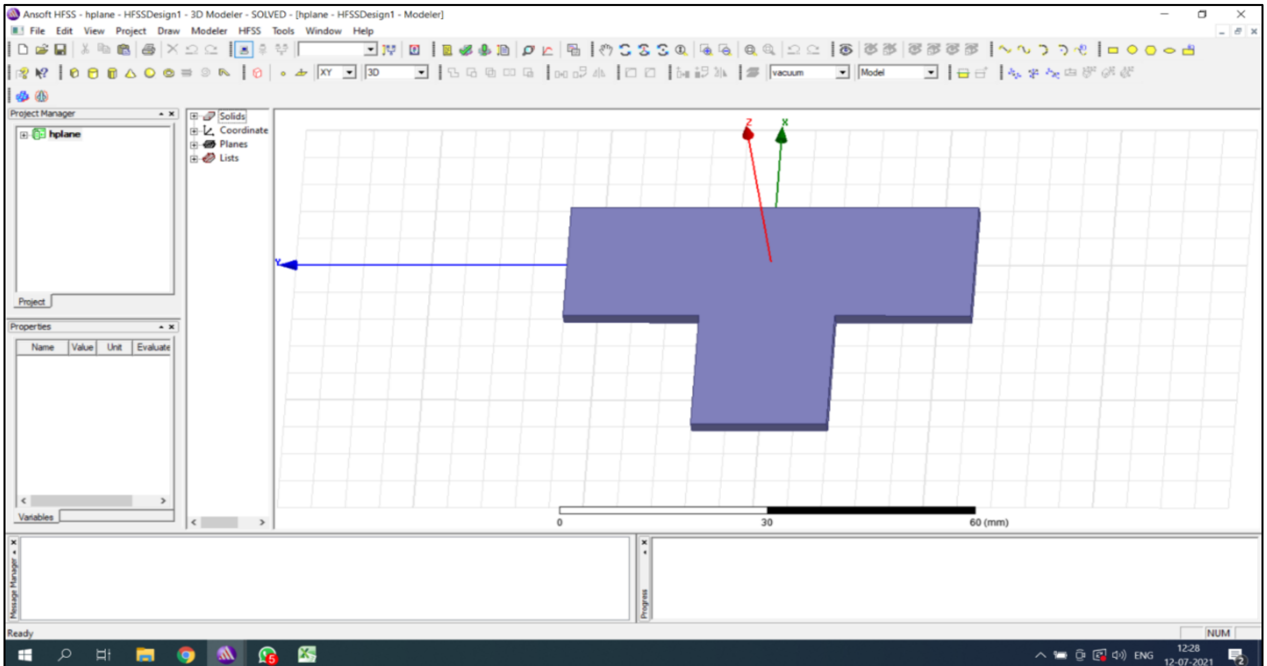
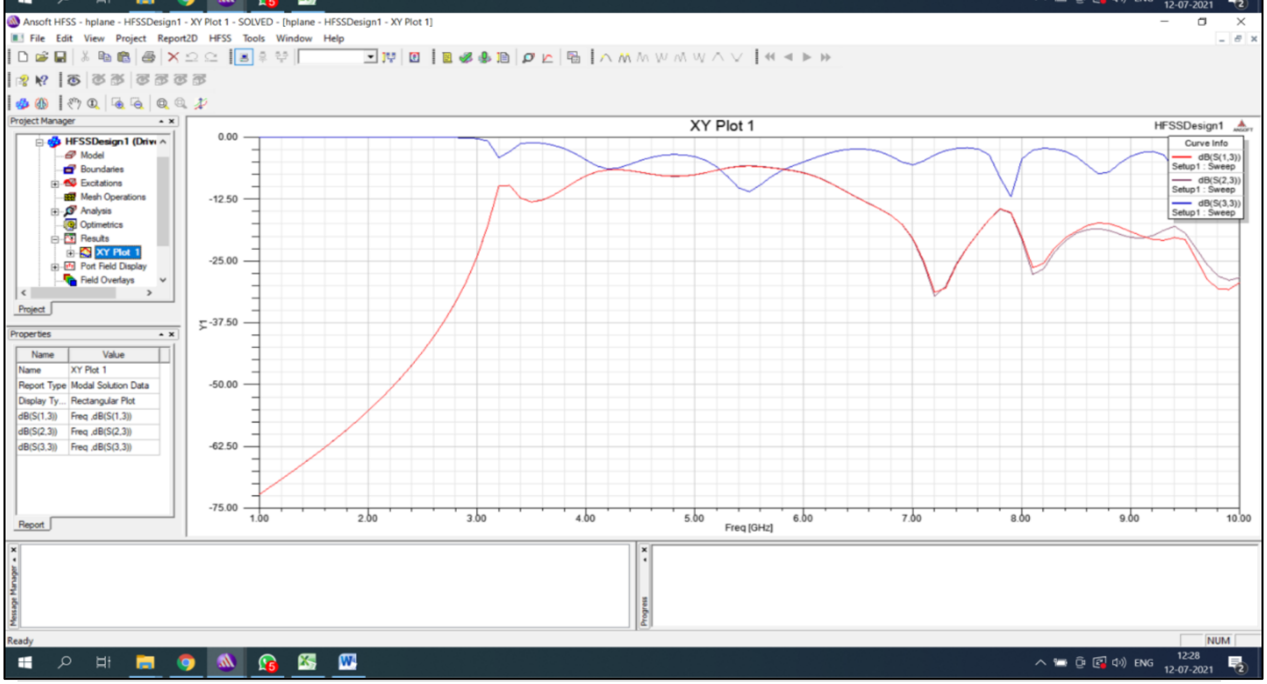


Fig. 5.2: H-Plane Tee Diagram

OUTPUT:





RESULT: H-plane Tee using HFSS Software has been studied and verified successfully.

DISCUSSION:

- Folded H plane tee is one of the many components that can be used for the power division application.
- Its advantage is that the output arms and input arms are in a single plane along a single axis, thus taking less space in the overall system.

EXPERIMENT-12

OBJECTIVE: To study and verify E-plane Tee using HFSS Software.

SOFTWARE USED: HFSS Software

THEORY: E-plane tee are series type tee-junction and consist of 3-section of waveguide joined together in order to divide or compare power levels the signal entering the first port at this or junction will be equally divided at second and third port of the same magnitude but in opposite phase.

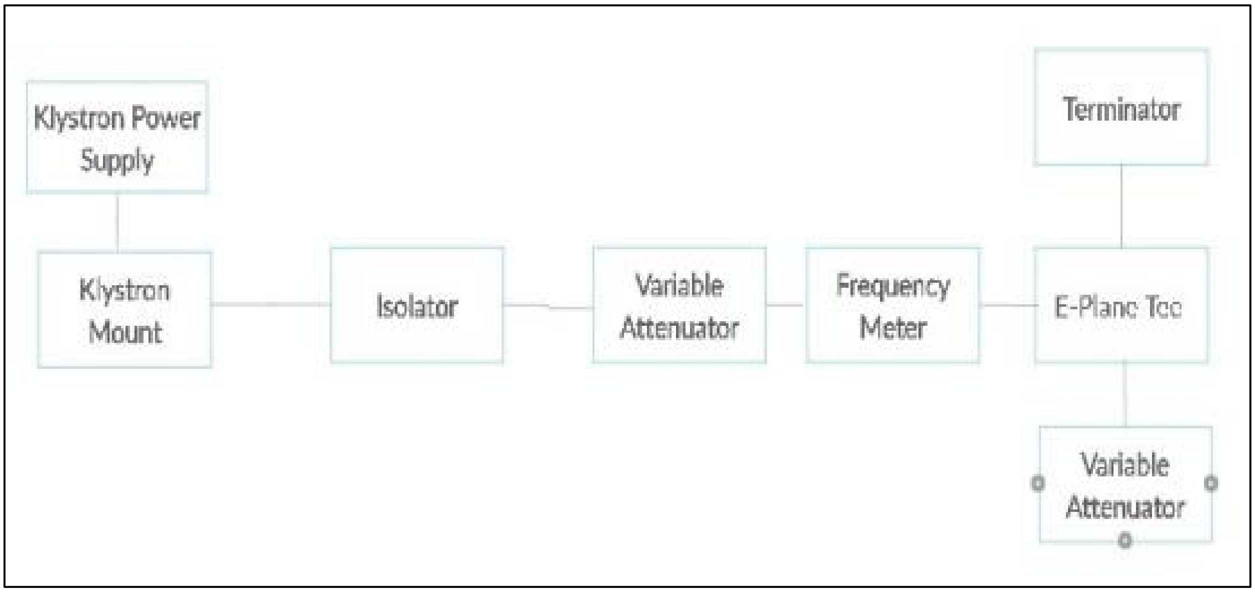


Fig. 4.1: Setup Component and Equipment

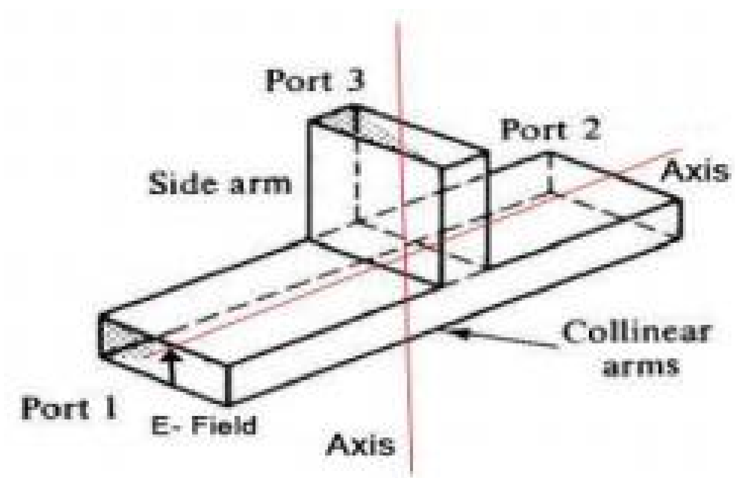


Fig. 4.2: E-Plane Tee Diagram

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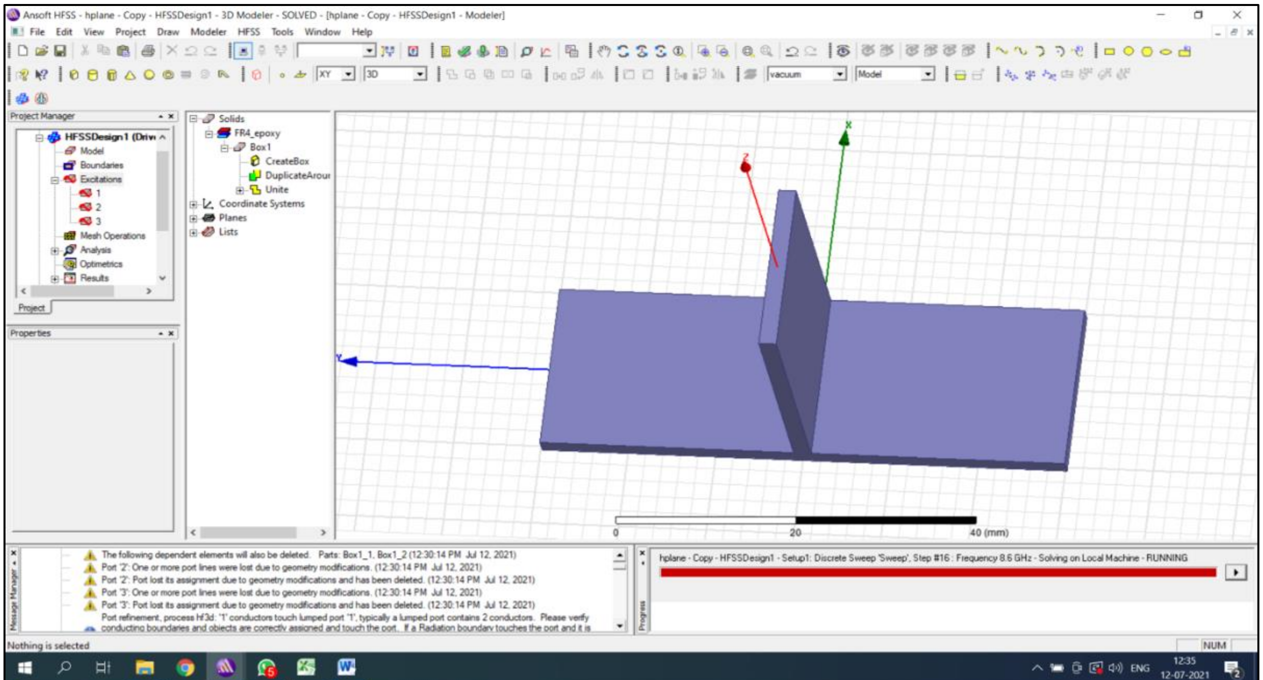
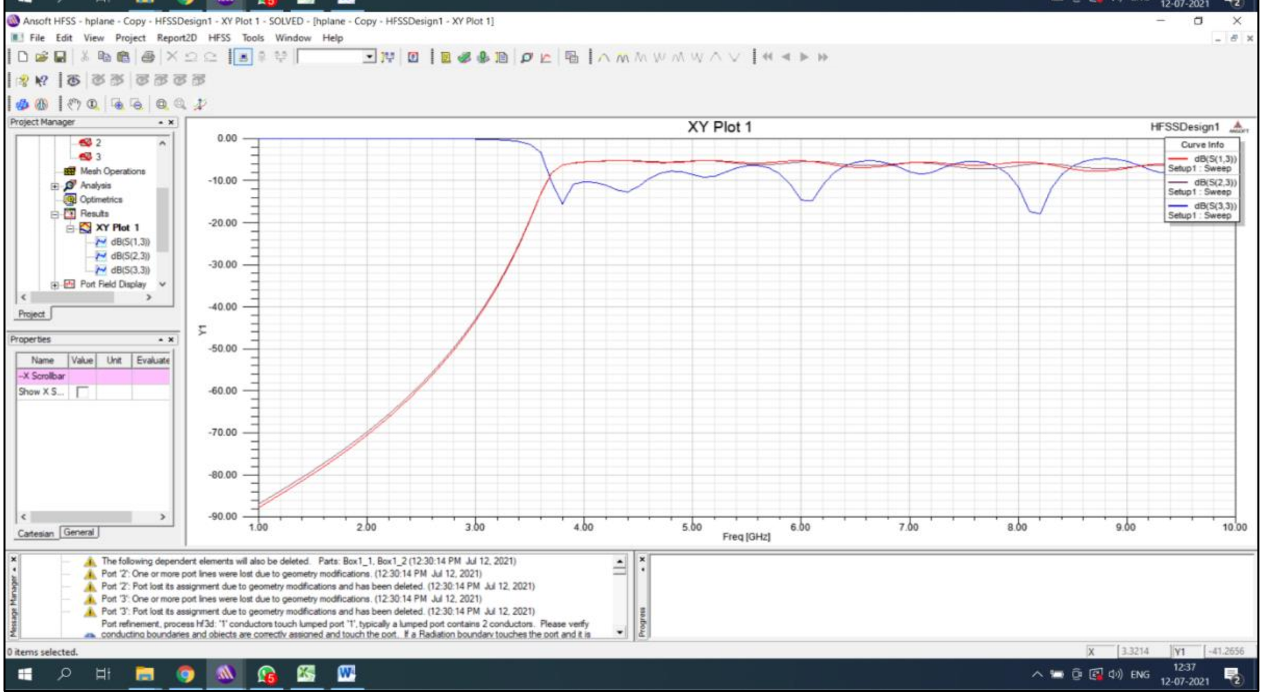
OUTPUT:





RESULT: E-plane Tee using HFSS Software has been studied and verified successfully.

DISCUSSION:

- An E-Plane Tee junction is formed by attaching a simple waveguide to the broader dimension of a rectangular waveguide, which already has two ports.
- E-plane Tee is also called as Series Tee.

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